4.3 Newton's Universal Gravitation

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$$F_g = \frac{G m_1 m_2}{R^2}, \quad G = 6.67 \times 10^{-11} \frac{N \cdot m^2}{kg^2}$$

F_g directly proportional to the masses and inversely proportional to the distance between the centers of the masses squared.

Ex pg142

Practice pg142 #1 a) 7.5×10^{-8} N
b) 3.0×10^{-7} N $4F_g$

Field Explanation

- scientists invented the concept of fields to explain how a force can exist between 2 objects not in contact.

- a mass is surrounded by an invisible gravitational field and can interact with another mass' field.

- gravitational fields are vectors

gravitational field strength

$$g = \frac{F_g}{m}$$

F_g ← Force of gravity on a test object

m ← mass of the test object

$$g = \frac{GM}{R^2}$$

M ← mass producing the field

R^2 ← distance from the centre of the field producing object.

Note: R is the distance from centre, so
"500km above surface of $\oplus$" means

$$R = \left(500\cancel{km} \times \frac{1000m}{1\cancel{km}} + 6.38\times10^6 m\right)$$

radius of $\oplus$

Weightlessness

- actually "apparent" weightlessness - zero force felt from supporting structures

ex: roller coaster
descending in elevator
running
vomit comet
orbit (constantly falling)

$F_c = F_g$

Orbit

- speed needed to stay in circular orbit around $\oplus$

m_s = mass of satellite
R = from satellite to centre of $\oplus$

$$F_c = F_g$$

$$\frac{\cancel{m_s} v^2}{\cancel{R}} = \frac{G M_\oplus \cancel{m_s}}{R^{\cancel{2}}}$$

$$\boxed{v = \sqrt{\frac{G M_\oplus}{R}}}$$

- period of a satellite

circumference of a circle

time to go around once

$$v = \frac{2\pi R}{T} = \sqrt{\frac{G M_\oplus}{R}}$$

$$\frac{T}{2\pi R} = \sqrt{\frac{R}{G M_\oplus}}$$

$$\frac{T}{2\pi R} = \frac{R^{1/2}}{\sqrt{G M_\oplus}}$$

$$T = \frac{2\pi R^1 R^{1/2}}{\sqrt{G M_\oplus}}$$

$$= \frac{2\pi R^{3/2}}{\sqrt{G M_\oplus}}$$

solve for T

$$\boxed{T = \frac{2\pi R^{3/2}}{\sqrt{G M_\oplus}}}$$

once solve for T

$$\boxed{T = \frac{\;}{\sqrt{GM_\oplus}}} \qquad = \frac{2\pi R^{3/2}}{\sqrt{GM_\oplus}}$$

- Escape Velocity
  - the speed needed to overcome the force of gravity.

$$E_k = E_p$$

planet

test object

$$\frac{1}{2}\cancel{m}v^2 = \frac{GM\cancel{m}}{R}$$

$$\boxed{v = \sqrt{\frac{2GM_{planet}}{R}}}$$

Gravitational Potential Energy

$$E_p = m(g)h$$

$$= m\left(\frac{GM_\oplus}{R^{\cancel{2}}}\right)\cancel{R}$$

$$E_p = \frac{GM_\oplus m}{R}$$

in text

mass of planet

mass of test object

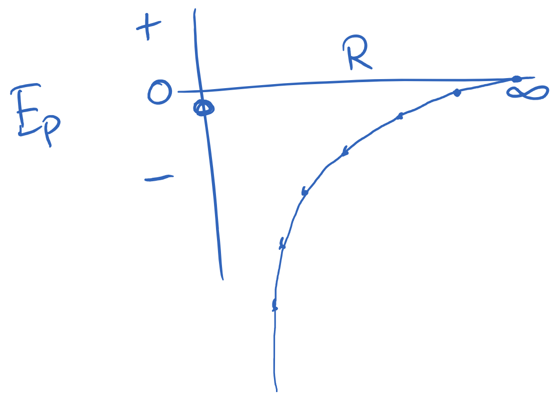
$$\boxed{E_p = -\frac{GMm}{R}}$$

Why is it negative?

At the surface $E_p = 0$ (normal $E_p = mgh$ calculations)

BUT – we define $E_p = 0$ when 2 objects are infinately far apart $\left(E_p = \frac{GMm}{\infty} = 0\right)$

- as objects get closer, E_p decreases
- $\therefore$ decreasing from zero, yields a negative #



Practice pg 143 # 2,3
pg 145 # 1-4
pg 146 # 1-2
pg 148 # 1-2